

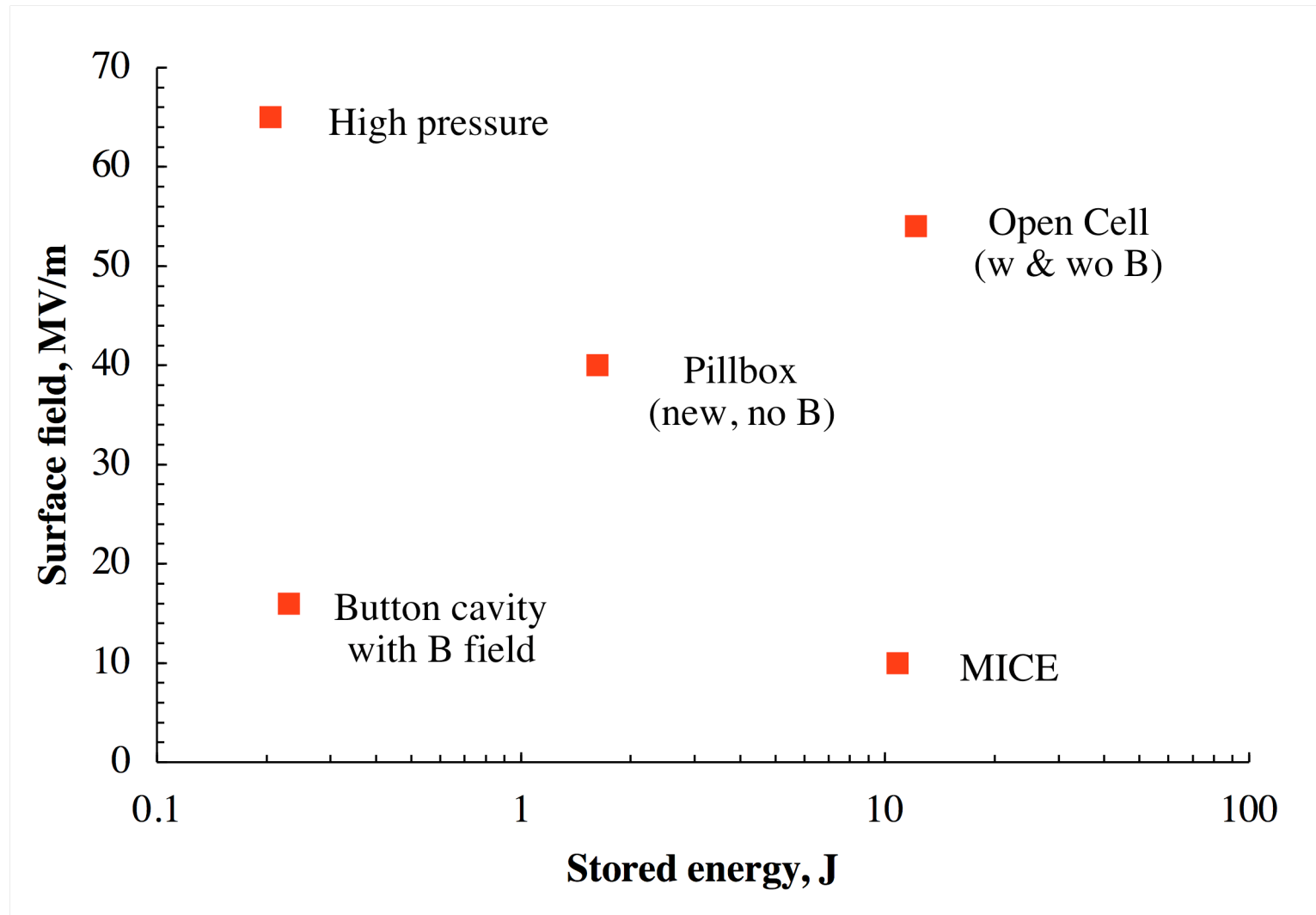
Comments on rf Breakdown

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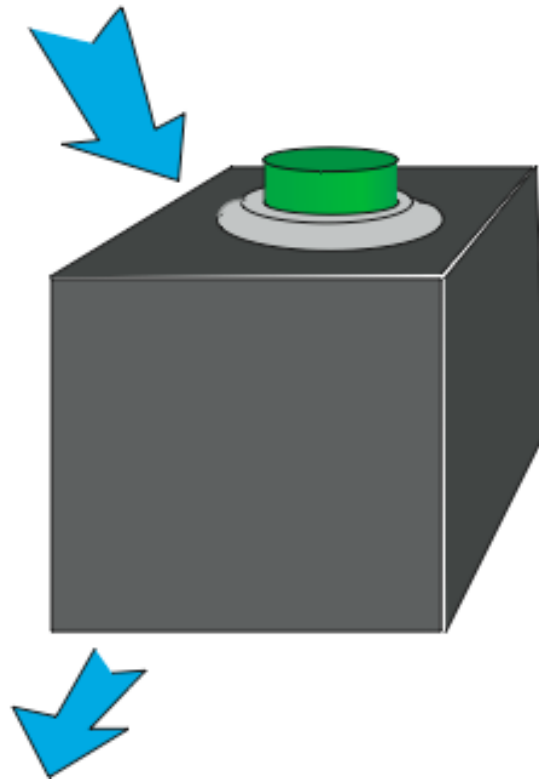
Our experimental program does not cover all the ground.



So we developed a model.

Minimal assumptions

E_{surf} , Surface Parameters, Plasma model, Molecular Dynamics



Something straightforward

Maximum Output

Breakdown rate, Pulse length, Electric field, Materials dependence, Conditioning procedures, The fully conditioned state, Gas type, Gas pressure, Magnetic fields,

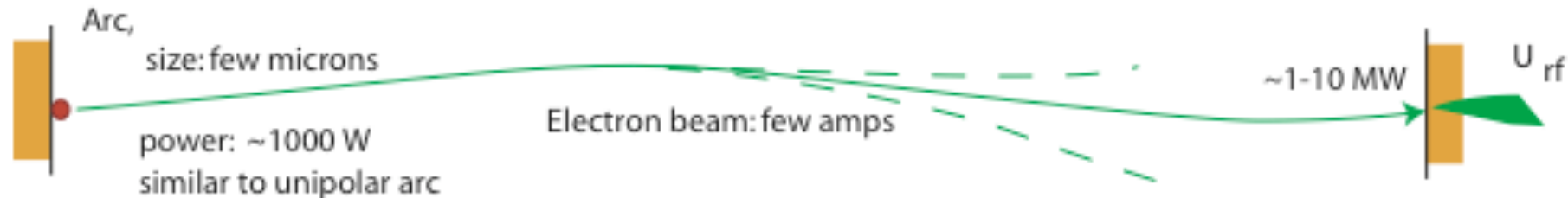
Frequency dependence, DC gaps, Temperature dependence, Correlated breakdown events, Timescale of breakdown process, Plasma spots, Crater clustering, PS and geometry dependence of gradient limits, Surface heating, Fatigue, Disappearance of field emitters during breakdown, Simple failure of atom probe tomography systems, Surface morphology, Superconducting systems, Positive and negative potentials, enhancement spectra, breakdown thresholds, time development of arc, termination of discharge, Arc loading, Optical spectra, Ionization mechanisms, Mitigation of Breakdown , Mitigation of field emission

etc.

There are two parts:

1) A plasma arc model

- Should explain all experimentally measurable features of rf arcs
- At the moment limited by computation problems. (this will be fixed)

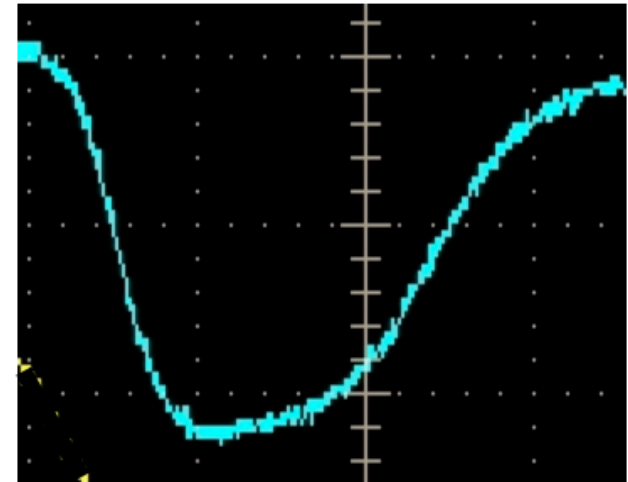
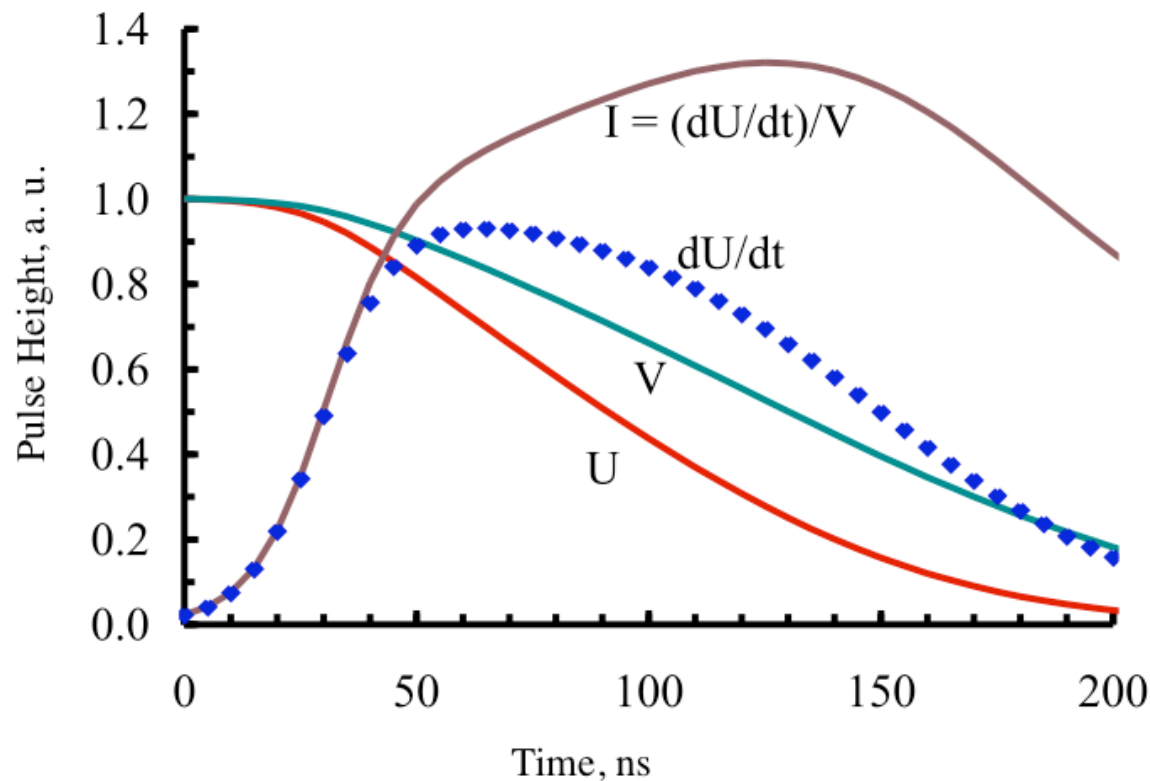


2) A model of the equilibrium between gradient and wall damage.

- explains how gradients depend on pulse length, power etc.

What is happening in arcs?

- X ray data show how energy leaves the cavity.

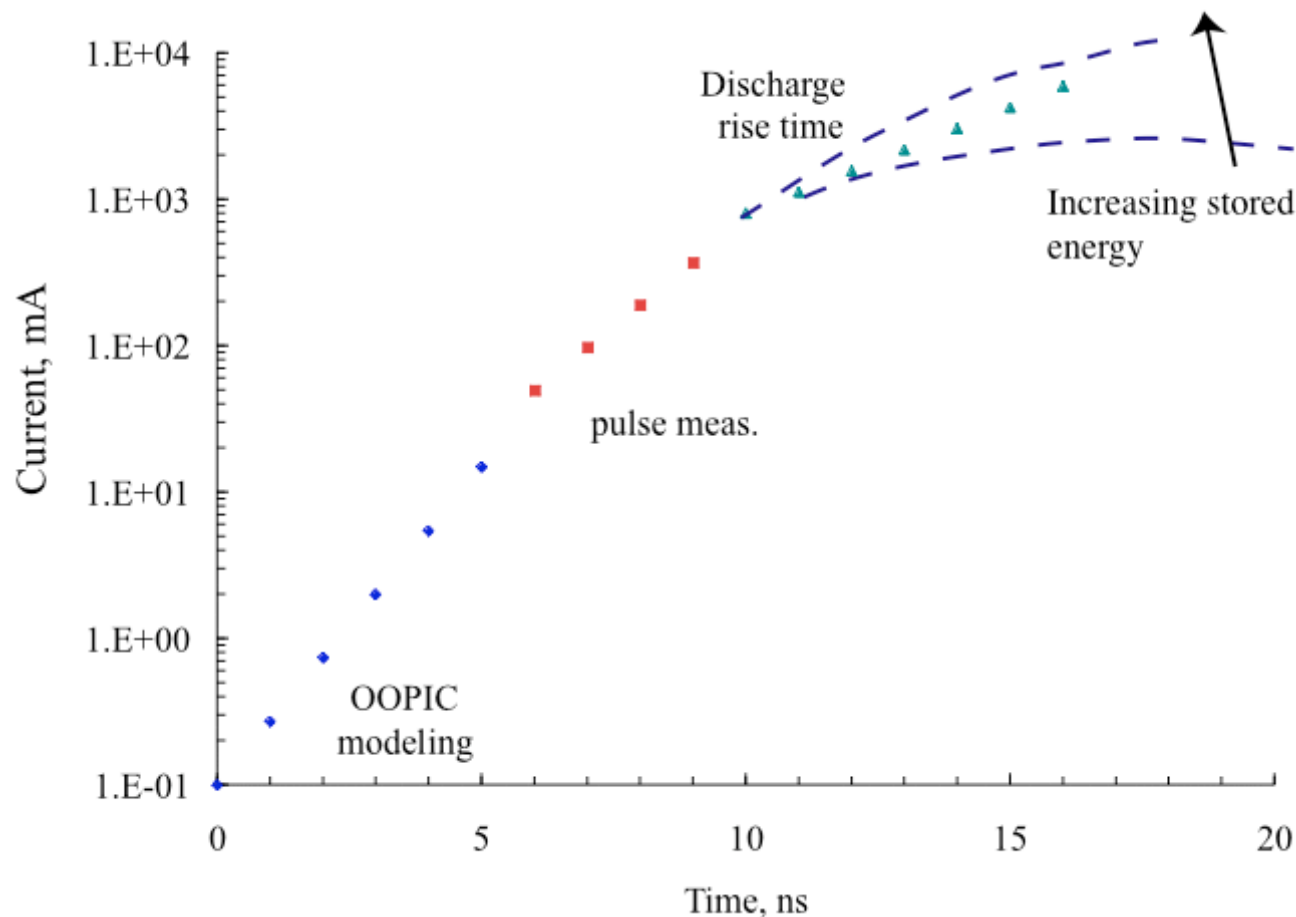


At the MTA our 805 MHz pillbox has:

- Stored Energy ~ 1 J
- Electron energy ~ 4 MeV
- Electron current ~ 4 A

Time development of a discharge

- The initial few ns have been modeled in detail in OOPIC Pro.
- The end of the breakdown event can be measured in a cavity.
- The whole discharge can be modeled and is experimentally accessible.



This model should be able to explain all the data.

Some mods. are required for specific applications.

Predicts positive polarities, DC, etc. break down at roughly the same fields.

For example: high pressure gas

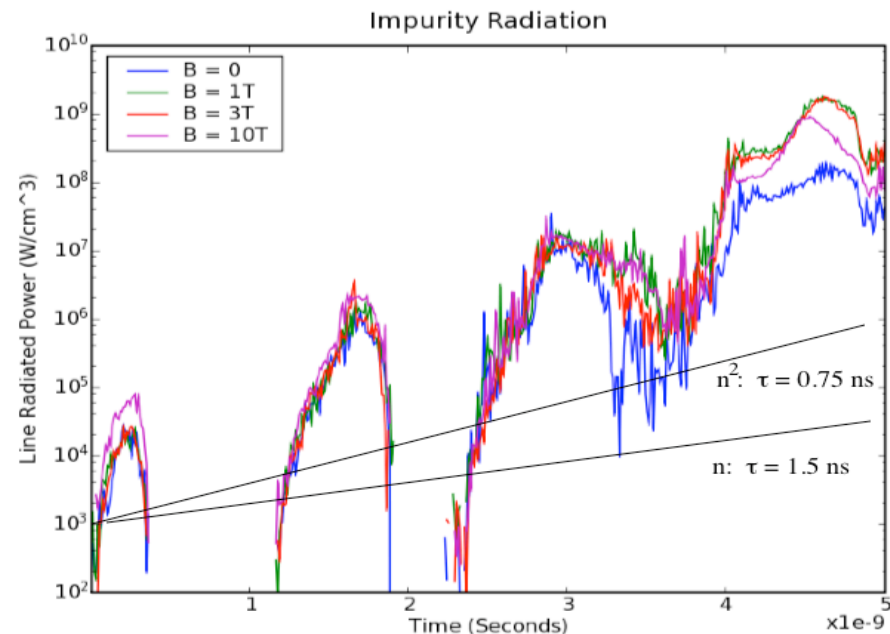
June 04, predict similar breakdown properties for metals as in vacuum

May 06, Experimental data showing radiation induced Q loss in gas filled cavities

March 07, predict breakdown due to high energy δ ray runaway

Magnetic fields require more modeling, but preliminary data is interesting.

B fields seem to make the plasma more confined.



Bob uses SLAC data to compare tensile strength.

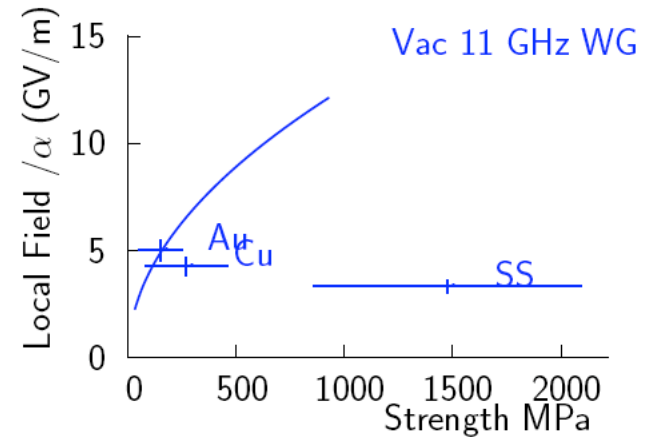
The Cu data, from EPAC02, disagrees with more recent data by a factor of about 2.

Lab G, SLAC and KEK agree.

The comparing metals is difficult because of unknowns in surface, ϕ , oxide properties, etc.

The experiment itself is very hard, (isolating X rays from many different backgrounds, considering low energy absorption, fitting PMT voltages, etc.) and the paper specifically stated they didn't calculate enhancement factors.

The unknowns in the surface, ϕ , oxide properties also make calculating resistive heating difficult, and the same comments on the data apply.

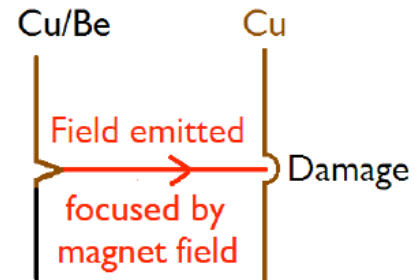


It is not obvious that dark current optics cause breakdown.

Dark current beams are ~ 1 mA.

Dep. energy $\sim 100 \mu\text{J}$, for 805 parameters.

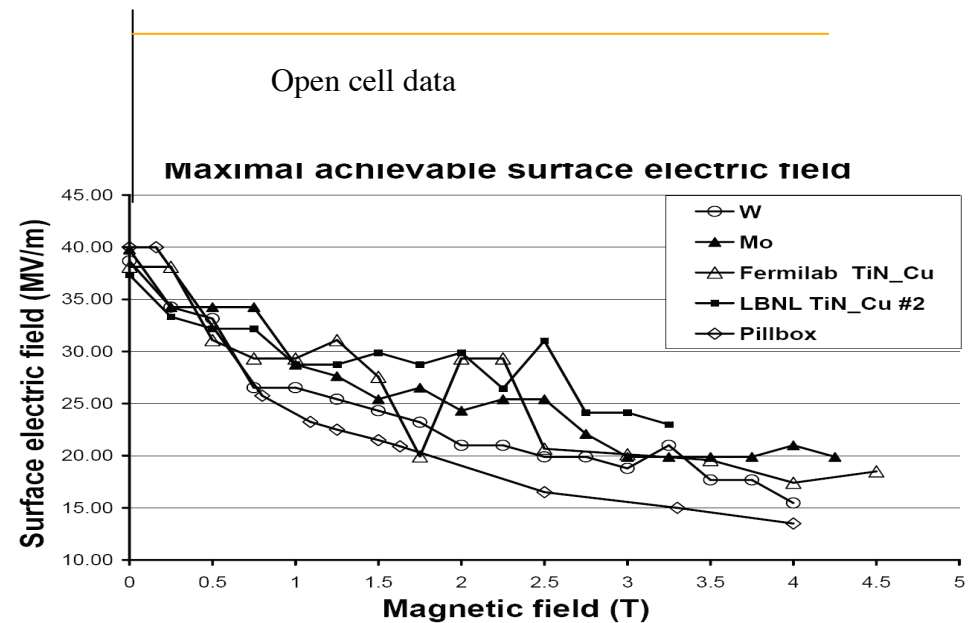
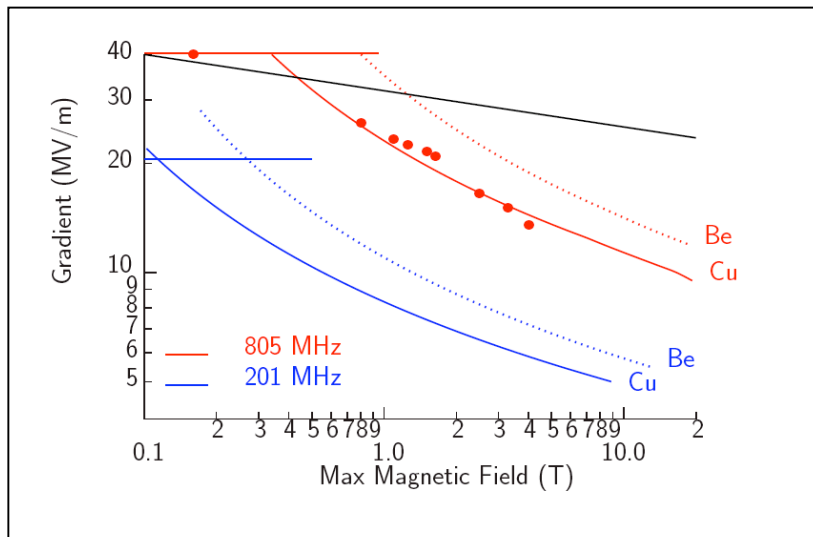
1 - 10 J produced in BD events.
seems to be OK (sometimes)



1. "Dark Current" electrons accelerated and focused by magnetic field
2. Melt small spots
3. If on a location with high surface rf gradient: breakdown
4. If not, no breakdown, but eventual damage

And the model does not fit the data.

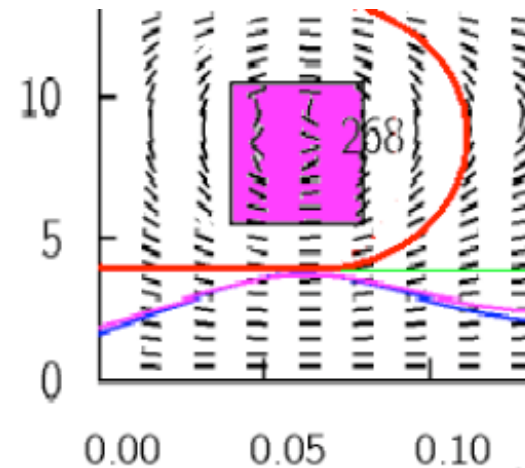
The open cell cavity seemed to be free of B field problems once it was reconditioned



"Magnetic Insulation" may have problems.

In limiter tokamaks, magnetic fields are parallel to the surface and they have arcing problems.

Unipolar arcs, which people don't study much any more, can shoot around the surface driven by $I \times B$ forces, perhaps spraying the inside surface with metal drops.



Summary

We need to study the interactions of plasma with magnetic fields.

The angle of the wall may be a very important parameter. This seems to be the primary difference between the open cell cavity and the pillbox

More stored energy in our experiments would be welcome.

ALD still seems to be a reasonable option.

More ideas are welcome.